SIZE DISTRIBUTION OF INTERPLANETARY IRON AND STONY PARTICLES RELATED WITH DEEP-SEA SPHERULES

H. Matsuzaki and K. Yamakoshi
Institute for Cosmic Ray Research, University of Tokyo, Tanashi, Tokyo 188, Japan

To study origin and evolution of the interplanetary dust, it is very important to investigate the size distribution. Here the changes of the size distribution of meteoroid particles due to the ablative effects during atmospheric entry were investigated by numerical computer simulation. Using the results, the pre-atmospheric size distribution of the interplanetary dust particles could be estimated from that of ablated spherules taken from deep-sea sediments. We are now analyzing deep-sea spherules from some aspects and examining if we could get any information about the interplanetary dust.

Fundamental equations of the numerical simulation are followed[1] ;

$$(1)\, dp/dt = Mdv/dt = -\rho_{atm} vAv + Mg, \qquad (2)\, 1/2\, \rho_{atm} Av^3 = \pi s^2 \varepsilon \sigma T^4 - LdM/dt,$$

$$(3)\, A = 1/4\,\pi s^2, \qquad (4)\, M = 1/6\,\pi \rho s^3, \qquad (5)\, -dM/dt = \pi s^2 p_e (\mu m_H/2\pi kT)^{1/2}.$$

(p, M, v, s, ρ: momentum, mass, velocity, diameter, density of the meteoroid particle; ρ_{atm}: atmospheric density; g: gravitational acceleration; ε: emissivity(=1.0); σ: Stephen-Boltzmann constant; L, p_e, μ: latent heat of vaporization, vapor pressure, molecular weight of the meteoroid material; m_H: mass of the hydrogen atom; k: Boltzmann constant)

(1) is the equation of motion, in which the momentum change of the meteoroid particle going through the atmosphere is equal to sum of the momenta of colliding air molecules and gravitational effect. Here, we can set dp=Mdv if evaporating mass is to dissipate in 4π direction. (2) represents energy balance. Kinetic energy transported to the meteoroid particle by colliding air molecules is to be dissipated through radiation and ablative mass loss. We set (3) and (4) so that the maeteoroid particle is spherical. Mass loss rate is determined by (5). p_e is a function of temperature of the meteoroid, T, such that; $p_e(T) = 10^{-1+c2/T}$ (in MKS units). So, in practice, we solve (2) as the equation of T. The value of ρ_{atm} at each altitude is taken from U. S. Standard Atmosphere of 1976. In this study, two kinds of meteoroid particles, iron and stony, were taken. Physical properties of the materials used in this calculation are presented in Table 1 [2,3]. The calculation starts at the meteoroid altitude 190km at t=0, then equations (1) to (5) are solved at every 0.02 seconds. The calculation is terminated if the altitude is over 250km or below 50km, or the velocity becomes less than 1km/s.

Parameters in this calculation are the initial size of the maeteoroid particle, s_0, atmospheric entry angle, θ (in the case of perpendicular input, $\theta=90°$), and initial velocity, v_0. 7920 atmospheric entry events with various (s_0,θ,v_0) value combinations ranged $10\mu m < s_0 < 1000\mu m$, $0° < \theta < 90°$, and $11.2km/s < v_0 < 20.2km/s$ were calculated. To these 7920 events, pre-atmospheric (initial) size distribution; $dn \propto s_0^{-A} ds_0$, entry angle distribution; $dn \propto -d(\cos 2\theta)$[1], and initial velocity distribution; $dn \propto v_0^{-5.4} dv_0$[4], were taken into account, where dn represents the number of particles (or probability) having initial size between s_0 and s_0+ds_0, entry angle between θ and $\theta+d\theta$, and initial velocity between v_0 and v_0+dv_0, respectively. Index value A in the initial size distribution, we call "the initial index A" here after, was varied from 2 to 7. To each initial index A, the final size distribution was counted out in accordance with these three distributions. For example, the final size distribution was found to be shown as Fig. 1 in the case of iron material and the initial index A=4.5. (In this diagram, relative population before atmospheric entry is to be unity with parameter s_0 between 45μm and 55μm, and parameter v_0 between 13.7km/s and 14.7km/s.) In Fig. 1 we can see that the final size distribution is also expressed nearly as; $dn \propto s^{-B} ds$, and the final index B is found to be 5.9 in this case. Fig. 2 was obtained by calculations in cases of various initial indices A and counting out the correspoding final indices B. The relation between the initial index A and the final index B was found to be formally as; B = 1.20A + 0.40 (Iron). Similarly, about stony material particles, the relation was such that; B = 1.45A - 0.25 (Stony).

Using these relations, we can estimate the pre-atmospheric size distributions of iron and stony meteoroid particles inversely by measuring that of ablated iron and stony spherules taken from deep-sea sediments. Both

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iron and stony spherules were picked up from the same fraction of sediments which had been taken as a dredged sample : GH79-1, St.1476 (9°49.96'N, 167°17.68'W, 5151m-depth). In this work, iron spherules in size larger than 80μm were counted, whereas many smaller ones exsisted. Stony spherules smaller than 100μm were rarely found, so the almose of all stony spherules could be thought to be picked up from the fraction. The results were showed in Fig. 3 in cumulative numbers with some other studies'[5,6,7]. Iron spherules are found to have the gradient -1.9~-2.5 in Fig. 3, that is, the final index B = 2.9~3.5 (Iron). Using the relation obtined before, we get the initial index A = 2.1~2.6 (Iron). Similarly, in the case of stony spherules, the final index is; B = 4.8~5.0 (Stony), and then the initial index is; A = 3.5~3.6 (Stony).

Dohnanyi (1972)[8] gave the size distribution of the interplanetary meteoroid particles as; dn $\propto$ $s^{-4.5}$ds (s~100μm). More recently, we can get from the data compilation of Grün et al. (1985)[9]; dn $\propto$ $s^{-4.0\sim-4.6}$ds (s~100 μm). These size distributions are consistent with that estimated from the stony spherules. However, the iron spherules themselves have smaller index of size distribution (2.9~3.5) so that estimated index of pre-atmospheric size distribution (2.1~2.6) is much smaller than that of the interplanetary meteoroid particles (4.0~4.6). As a consequence, it is suggested that the major components of the interplanetary meteoroid particles are stony particles, and that, in the interplanetary space, iron particles have different size distribution from stony ones in the size range around 100μm.

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Table 1. Physical properties used in the calculation

	Iron	Stony
Material Density ρ (g/cm^3)	8.0	3.0
c_1	9.607	9.6
c_2	-16120	-13500
Latent heat of vaporization L (J/kg)	6.4×10^6	6.05×10^6
Molecular weight μ	56	45

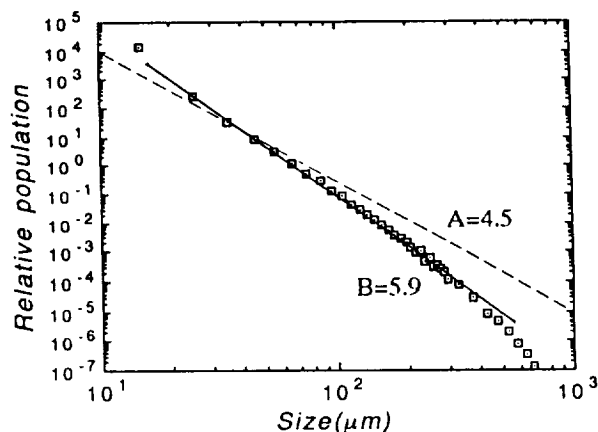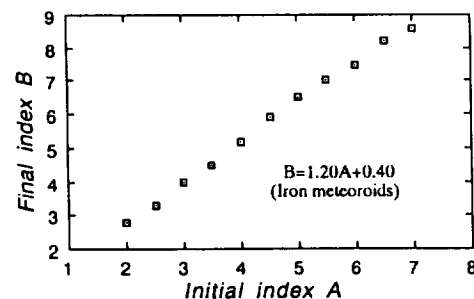Figure 2. Relation between the initial index A and the final index B

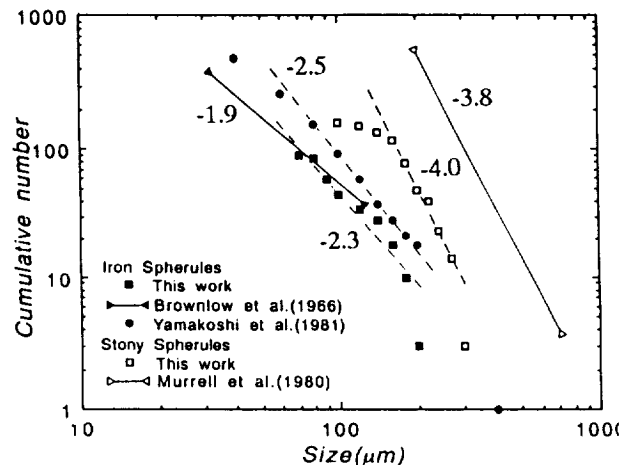Figure 1. The final size distribution of iron meteoroid particles in the case of the initial index A = 4.5

Figure 3. Cumulative size distributions of deep-sea spherules